Braze Oven Simulation

Nick Hansen

Solution Time 2616 (s)
Introduction

- ATS manufactures engine cooling components for both on- and off-highway applications
- Cooling cores are generally composed of airfins, tubes, headers/tanks, and sidesheets
- In order to fuse an assembled core, a process called brazing is used where the temperature of the core is raised enough to melt the outer clad layer on the aluminum
- Once the clad layer melts, it flows to part-to-part contacts
- The core is then cooled, fusing the joints together

Core matrix is constructed using a corebuilder.

Headers are pressed onto the tubes in core.
Introduction

• ATS’s robust core design allows us to manufacture a wide variety of core sizes to fit our customer’s applications

• Applications range from large scale mining equipment to small skid-steer tractors

• Currently new cores are matched to 1 of 9 brazing profiles to allow for adequate bonding
Introduction

• A single profile braze line would provide the most efficient manufacturing process
• Single profile benefits
  – a continuous process flow is easier to plan for
  – no staging areas are required
  – on-floor inventory is reduced
  – no profile change-over times
• The overall annual cost savings from reduced time and labor are estimated to be $110,000
Modelling – Material Properties

• General core component/oven sizes
  – Tube material thickness: 0.4 mm
  – Airfin material thickness: 0.1 mm
  – Header material thickness: 1.0 mm
  – Total oven length: 41 m
• A bulk solid was used to model the core volume
  – Density and specific heat were mass-averaged
  – Thermal conductivity was volume averaged
Modelling – Braze Fixtures

- Braze fixtures hold a core together once it is compressed in a core builder
- They add a considerable amount of mass to the core
- Larger cores ride on metal skids
- Oil coolers use an extruded tank that is brazed on
- The tanks cause a high mass concentration at the ends of the cooler
Modelling – Conveyor Belt

• The oven consists of a deoiler, fluxer, dryer, forced convection zone, transition zone, 4 radiation zones, vacuum cool zone, and fan cool zone

• Controls for the modelled region include the temperatures of the convection and 4 radiation zones and the belt speed of the conveyor carrying the cores through the oven

• A set of these controls is known as a braze profile

• A small section of the oven was modelled and the nitrogen atmosphere was passed over the core

• Temperature changes of the oven wall and inlet nitrogen were controlled by field functions
Modelling – Forced Convection

- The forced convection zone contains two fans that move nitrogen through the cores from above.
- The cores, as modelled, are solid and impermeable.
- Fan interfaces and momentum sources were difficult to control in a transient model where the fan moves through the model space.
- The forced convection was modelled as a volumetric heat source.
- The heat source was controlled by a convection field function based on the cell temperature of the core and the temperature set point of the forced convection zone.
- The convection coefficient was calibrated to measured temperature data from the brazing process.
Mesh Setup

- Trimmer Mesh
  - Base Size: 25.4 mm
- Largest Model
  - 341000 cells
- Smallest Model
  - 235000 cells
Physics Setup

- Core
  - Implicit Unsteady
  - Solid with averaged material properties
  - Time dependent volumetric heat source

- Frame
  - Implicit Unsteady
  - Solid with averaged material properties

- Oven
  - Implicit Unsteady
  - Gas
  - S2S Radiation
  - Time dependent inlet temperature
  - Time dependent wall temperature
  - Radiation reflective inlet and outlet
Model Validation

- Cores are thermocoupled as a manufacturing quality check to ensure current production cores are fully brazed.
- A high-temperature data acquisition unit is required to survive the braze ovens.
- Cores are typically thermocoupled in the center and the four corners.
- Temperature point probes were placed in each simulation to match production test data.
Model Validation

21093

- 3 row radiator
- 800 x 845 x 77 mm
- 14.6 kg core
- 5.6 kg braze frame
- Profile 22
21107

- 2 row radiator
- 660 x 660 x 50 mm
- 8.4 kg core
- 4.6 kg braze frame
- Profile 22
Model Validation

21377

- 76 mm charge air cooler
- 850 x 680 x 76 mm
- 15.4 kg core
- 5.0 kg braze frame
- Profile 23
Model Validation

22158
- 76 mm charge air cooler
- 510 x 225 x 76 mm
- 3.9 kg core
- 3.9 kg braze frame
- Profile 21
22319

- 126 mm charge air cooler
- 1200 x 1485 x 126 mm
- 123 kg core
- 33.7 kg braze frame
- Profile 24
Model Validation

22714

- 5 row radiator
- 1160 x 812 x 132 mm
- 38.9 kg core
- 9.4 kg braze frame
- Profile 24
Model Validation

22801
- 2 row 47 mm oil cooler
- 870 x 572 x 105 mm
- 21.7 kg core
- 9.6 kg braze frame
- 9.2 kg tanks
- Profile 25
Model Validation

22842
- 1 row 47 mm oil cooler
- 1159 x 504 x 47 mm
- 15.1 kg core
- 12.8 kg braze frame
- 4.2 kg tanks
- Profile 24
Uniform Profile Search

1. Simulate cores to determine a valid braze profile
2. Send a thermocouple tree through the unloaded oven to calibrate the oven heater controls
3. Send a thermocouple tree through oven with thermocoupled dummy cores to check oven control
4. If oven control is insufficient, repeat 1-3 with an adjusted braze profile
5. Once a controllable profile is found, thermocouple production cores and perform metallurgy to verify braze
### Uniform Profile Search

#### Time Above (min)

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<th></th>
<th>Preheat</th>
<th>Transition</th>
<th>Zone 2</th>
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<th>Zone 4</th>
<th>Zone 5</th>
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</table>

#### Temperature (°F)

- **21093**

**Time (min)**: 0 to 40

**Temperature**: 0 to 1200

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**ADAMS Thermal Systems, Inc.**
Uniform Profile Search

21107

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Time Above (min)
### Uniform Profile Search

#### Temperature vs. Time Graph

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#### Table for Time Above (min)

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Uniform Profile Search

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The graph shows the temperature profile over time for different zones and samples. The table below provides the exact times for each zone and the time above specific temperature thresholds for each sample.
Uniform Profile Search

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Time (min)

Temperature (°F)

22714

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### Uniform Profile Search

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**Temperature (°F)**

- **Time Above (min):**
  - 1080: 7.5, 4.1
  - 1100: 7.4, 4.0

**Time (min)**

- 0 to 40
**Physical Testing**

### Unloaded Tree Testing

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<th>PH1</th>
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<th>Z2</th>
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### Loaded Dummy Core Testing

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